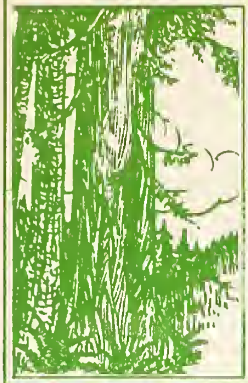

FOREST RESEARCH NOTES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION *
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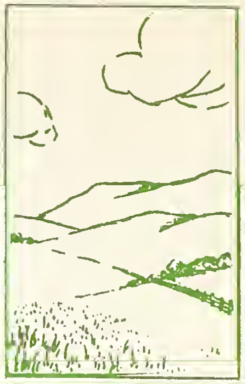

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WET WATER FOR FOREST FIRE SUPPRESSION[1/]

By

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In recent years wetting agents have been recommended by manufacturers and others for increasing the efficiency of water for fire suppression. Many local fire-protection agencies have made tests comparing wetting agent solutions with plain water for flame suppression and mop-up under field conditions. In general, their results and conclusions indicated the need for comprehensive tests to determine the types of wetting agents best suited for suppression and the best technique for application of chemically treated water, called wet water.

Such comprehensive research was begun in 1948 by the Engineering Department at the University of California at Los Angeles. Technical supervision of the research was administered by the Division of Forest Fire Research, California Forest and Range Experiment Station. In 1949 the Station took over all phases of the investigative work.

At the outset it was realized that a great deal of fundamental research would be necessary before specifications on all phases of suppression could be developed. For instance, those physical properties of water and chemicals accounting for the suppression action were not known. The research program was therefore divided into three parts: (1) Determining the physical properties of plain water and wet water; (2) investigating the mechanisms of fire suppression; (3) determining the suppression effectiveness of wet water over plain water.

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Physical Properties

The physical properties thought to be important in suppression are: surface tension, penetration, surface spreading, and foaming. Surface tension is a measure of the force required to hold a liquid drop in a spherical form. For instance, mercury has a high surface tension value (513 dynes/cm); water, a moderate value (72.8 dynes/cm); and alcohol and petroleum, low values (approximately 25 dynes/cm). Most wetting agents in concentration of one percent will reduce surface tension of water to 30 dynes/cm. The more active the wetting agent is, the more rapidly the surface tension of water is decreased. The recommended concentration for fire fighting is usually such as to reduce the surface tension of water to about 35 dynes/cm.

When the surface tension of water is reduced, spreading, penetrating, and foaming are increased. Tests of these physical properties were made on water and 14 commercial wetting agents. The tests show that:

1. Surface spreading of wet water on wood is 2 to 8 times greater than water, depending on species of wood.

2. Penetration into wood of wet water is about 8 times greater than water.

3. Penetration of wet water into charcoal is about 2/3 as much as it is for wood.

4. Penetration and surface spreading of water on charcoal is practically nil.

5. All wet water readily forms foam.

Corrosion tests with iron and galvanized iron showed that wetting agent solutions in general, unless they contain an inhibitor, have higher corrosion rates than distilled water. With few exceptions the rate of corrosion was greater for the galvanized iron. The corrosion of metals by wetting agent solutions may be wholly corrected by the addition of small amounts of chemicals, known as corrosion inhibitors, such as potassium dichromate and sodium nitrite. Tests showed that as little as 100 parts per million, or about 2 ounces per 100 gallons of water, of commercial granular potassium dichromate was effective in reducing the corrosion of iron and galvanized iron by wetting agent solutions.

Suppression Mechanism

Before tests with fires were begun, some important questions arose concerning the suppression action of water. First, what is the behavior of a water droplet when it strikes a burning wood surface? Calculations revealed that water, sprayed on burning wood with its surface reduced to charcoal, will impinge on the charcoal surface having a temperature as high as 1900° F. Second, what is the theoretical minimum volume of water necessary to cool a unit volume of burning wood below the rekindling point? Again, calculations showed that a unit volume of water suddenly applied over the entire surface will cool 300 volumes of burning wood below the kindling point; but if the water is applied only to the frontal area of the burning wood, the amount of water required is doubled. Third, does penetration cooling have an advantage over surface cooling and vice versa? Results of calculations indicated that there was no significant difference between penetration and surface cooling.

Suppression Effectiveness

Water may be used to an advantage in forest fire suppression for: (1) Flame suppression; that is, application of water on the flame to retard the spread of a given section of fire; (2) mop-up; that is, application of water on a burned area to extinguish small isolated flames and to cool glowing and charred material to a point at which rekindling is unlikely; (3) pretreatment; that is, application of water on unburned fuels in advance of an oncoming fire to retard its rate of spread or in holding a line from which to backfire. For each of these uses, fire tests were conducted to compare the suppression effectiveness of wet water and plain water.

Flame Suppression

For flame suppression, a total of 93 model fires were burned on which the effectiveness of 14 commercial wetting agents were tested. Besides these laboratory tests, 66 field-fire tests were made, in which three commercial wetting agents were tested. Each fire was allowed to burn up to its maximum flame intensity before suppression was started. The intensity of each fire was measured with a radiometer. From the radiometer record of each fire, the intensity during suppression was calculated.

The experimental work established the superiority of wet water over plain water in reduction of fire intensity. The superiority is at its maximum when the liquid is first sprayed on the fire. Results indicate that this superiority at the very beginning of spray application on a section of flaming front is from three to four times greater than at the end of application, when only isolated flames remain. For the period of flame suppression of these experimental fires, the mean superiority values of wet water over plain water are 1.70 for field fires and 2.10 for model fires. Ordinarily, superiority is expressed as a ratio of quantity of plain water used to quanitty of chemical solution used. The superiority of wet water based on quantities was 1.25 for field fires and 1.55 for model fires.

However, in recommending wet water for flame suppression emphasis is given to the superiority based on reduction of flame intensity. The practical importance of this superiority, especially at the beginning of suppression, is that it shows the decided advantage a hose operator has in advancing on a fire front with wet water. This advantage should permit an operator to knock down the flame intensity more quickly to a point where he can move in and hold the spread of a fire. It is believed, therefore, that the use of wet water in flame suppression should result in controlling a greater number of fires as well as in controlling the fires at an earlier period, thus reducing the size of the mop-up job. Even where an abundant supply of water is available, use of wet water in some instances may make the difference between success and failure in controlling a forest fire.

In these tests the ratios of volume of burning wood to volume of wet water used for flame suppression were: field fires, 56 to 1; model fires, 117 to 1. For fires suppressed with water the ratios were 45 to 1 for field fires and 76 to 1 for model fires. These ratios, when compared with 300 to 1--the maximum possible, show that there is room for improvement in techniques of application.

Experimental work has not yet advanced sufficiently to specify what pressures and discharge rates to use for most efficient flame suppression. It has been noted, however, that on the experimental fires sprays were superior to straight streams primarily because of their greater coverage.

Mop-up

To test the effectiveness of wet water in mopping up fires in deep pine litter, a total of 108 test fires were burned. The technique used in mopping up these fires consisted of first spraying the burned area as rapidly as possible, suppressing all glowing, smoking, and burning material; yet not wasting water or wet water by wetting the area unnecessarily. In this first application care was taken to hold the nozzle above the surface of the burning litter at a distance which gave minimum air entrainment and effective spray distribution with maximum coverage. The first application was followed by an intermittent application on those spots where smoke appeared. A quick-opening-and-closing shut-off nozzle permitted closing the nozzle quickly when moving from one smoldering spot to another and opening it only long enough to extinguish the immediate small hot area.

The results of 82 of these fires show that the superiority based on quantity of plain water used compared to quantity of wet water used is about 1.29. Thus, by the addition of wetting agents at appropriate concentration, a saving of 23 percent in the quantity of water can be realized on a given mop-up job. As intermittent application was used part of the time in mopping up these fires, the superiority of wetting agent solutions based on time of mop-up is only 1.15. This means a saving of 13 percent in time in mopping up a given burn. In practice the saving of 23 percent in quantity of water and 13 percent in mop-up time may appear as not being significant; however, on a national scale or even on one large burn such a saving can amount to a considerable sum of money.

Another factor of practical importance is that wet water in mop-up has a distinct advantage in reducing the rekindling from hot spots and glowing embers. For the mop-up tests in deep pine litter the ratio of rekindled spots on plots suppressed with water to the rekindled spots on plots suppressed with wet water was 1.43 to 1. For comparable fuel types one can expect approximately 30 percent fewer rekindlings on an area mopped up with wet water.

Pretreatment

Pretreatment experiments were made by spraying wet water and plain water on litter fuels to determine whether wet water would increase the length of time that wetting is effective. The results of these experiments indicate that the length of time for sprayed unburned litter fuels to dry is 50 percent longer for wet water than for plain water. This is attributed to the greater surface spreading and penetration of wet water.

Conclusions

Significant differences were found in physical properties among the wetting agent solutions tested. However, no special meaning can be attached to these differences because these same agents were not significantly different in their effectiveness in the fire suppression tests. It appears that the surface spreading, penetrating, and foaming properties of all the wetting agents tested, when the agent is used so as to reduce the surface tension of plain water by one-half, are within that range which does not alter the effectiveness of a wetting agent solution for fire suppression. The results indicate that on the basis of penetration and surface spreading, any one of the hundreds of wetting agents now on the market, if used at the proper concentration, would yield suppression-effectiveness results comparable to those obtained for the wetting agents tested.

Specific conclusions drawn from work performed to date are: (1) Savings up to 23 percent in the volume of water required and 13 percent in time of mop-up can be obtained with wet water if applied with reasonable efficiency; (2) rekindling is reduced as much as 30 percent on fires mopped up with wet water as compared with plain water; (3) foaming appears to be a desirable property of wet water in mop-up because it prevents channeling of the water; (4) wet water is markedly superior to plain water in its ability to knock down flames quickly, thus permitting access to a fire edge not otherwise accessible; (5) dead fuels along the burning edge of a fire or along a backfire line remain wet up to 50 percent longer when sprayed with wet water than when sprayed with plain water; (6) fuels once treated with wet water and allowed to dry may be sprayed later with plain water with results comparable to an original spraying with wet water; (7) most wetting agents increase the corrosive action of water, but this can be wholly corrected by the addition of chemicals known as corrosion inhibitors.

In general, the results to date have shown that wetting agents have a definite place in forest fire suppression. Certain information on foaming and dermatological effects, however, is still needed to permit the writing of definite specifications for the most desirable type of wetting agents. Some advancement has been made on technique of application for maximum effectiveness; but this knowledge is not yet complete enough to satisfy all field conditions. Experiments are still needed to determine the effect of form and pattern of spray on fire suppression efficiency, for plain water, wetting agent solutions, and other chemicals.